National Aeronautics and Space Administration

ARTEMIS SCIENCE

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Exploration Systems Development Mission Directorate

“The United States will Maintain its Leadership in Space Exploration and Space Science”

“Remain a global leader in science and engineering by pioneering space research and technology that propels exploration of the Moon, Mars, and beyond.”

“U.S. human and robotic space exploration missions will land the first woman and person of color on the Moon, advance a robust cislunar ecosystem, continue to leverage human presence in low-Earth orbit to enable people to live and work safely in space, and prepare for future missions to Mars and beyond.”

— The White House U.S Space Priorities Framework, Dec 2021

United States Space Priorities Framework
NASA 2022 Strategic Plan
2023 NASA Budget Request

NASA's Moon to Mars Objectives

A blueprint for future human exploration

SCIENCE

Conduct science on and around the Moon, using humans and robots to address scientific priorities about the Moon.

Demonstrate future science methods astronauts can use beyond Low Earth Orbit:

- Lunar/Planetary
- Heliophysics
- Biological/Physical
- Astrophysics

TRANSPORTATION AND HABITATION

Develop and demonstrate an integrated system to conduct human missions.

Live and work at deep space destinations and safely return to Earth.

LUNAR AND MARS INFRASTRUCTURE

Maintain continuous robotic and human presence on the Moon with multiple international and industry users to develop a robust lunar economy.

Create infrastructure to support initial human Mars demonstration and to continue exploring the solar system.

OPERATIONS

Conduct human missions on and around the Moon followed by missions to Mars.

Use a gradual approach to build, demonstrate, and operate new technologies to live and work on other planetary bodies.

Requested feedback on these objectives in summer 2022 from the following key stakeholders:

NASA workforce: our greatest asset

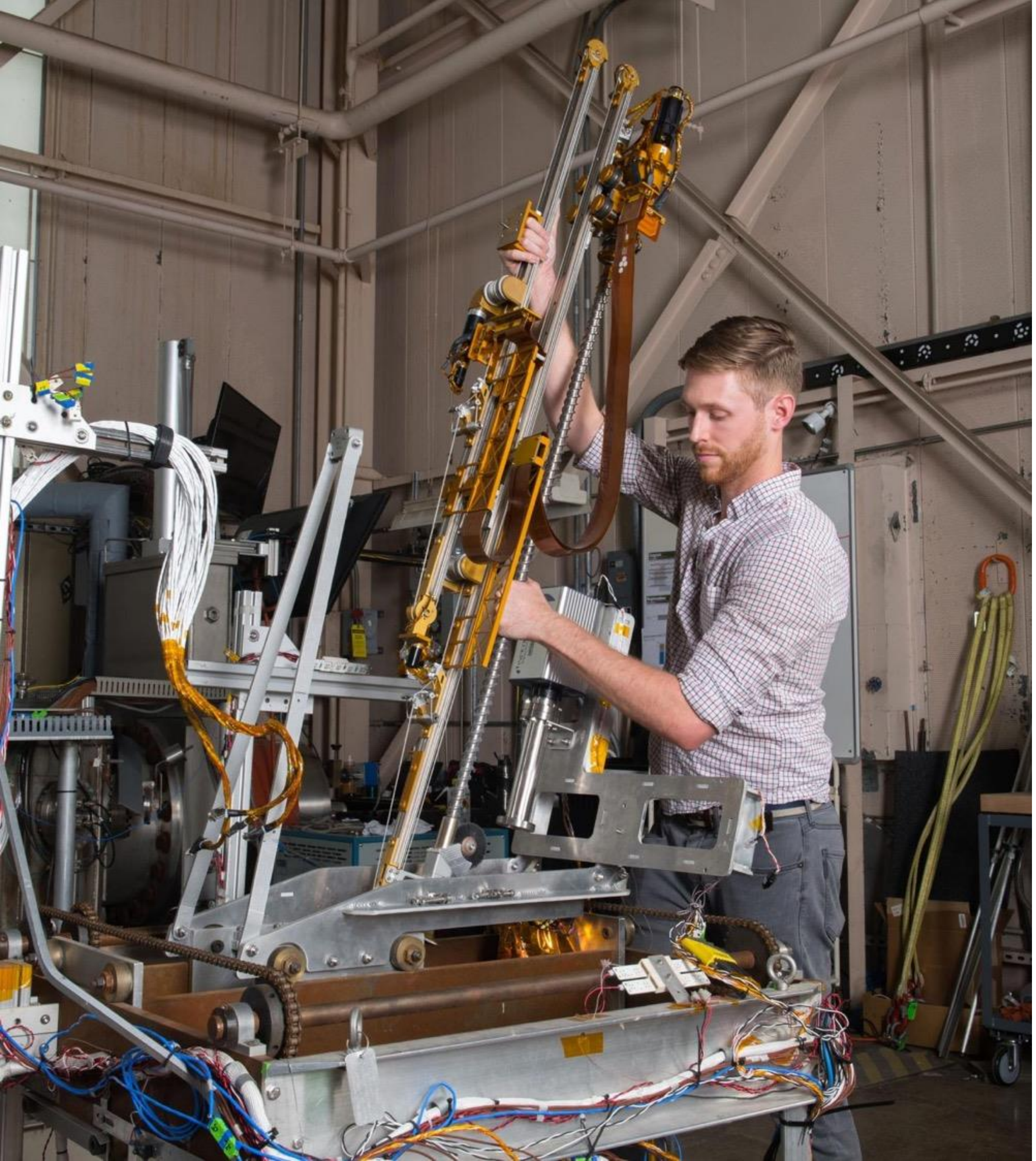
International partners: our key current and future, anticipated collaborators

U.S. industry, academia, DOE, NIH, NSF, etc.: our national leaders in space research and capabilities

Artemis Science Objectives

- Understand planetary processes
- Understand the character and origin of lunar polar volatiles
- Interpret impact history of Earth-Moon system
- Reveal the record of the ancient sun and our astronomical environment
- Observe the universe and the local space environment from a unique location
- Conduct experimental science in the lunar environment
- Investigate and mitigate exploration risks

Pictured left: NASA astronaut candidates and field instructors hike during geology training in Arizona



Artemis Technology Objectives

The **Lunar Surface Innovation Initiative (LSII)** works across industry, academia and government through in-house efforts and public-private partnerships to develop transformative capabilities like:

- In-situ resource utilization (ISRU)
- Surface power
- Dust mitigation
- Extreme environment
- Extreme access
- Excavation and construction

Pictured left: A Honeybee Robotics systems engineer installs The Regolith and Ice Drill for Exploring New Terrain (TRIDENT) on a trolley for thermal vacuum chamber testing. TRIDENT will drill up to three feet deep, extracting lunar soil and demonstrating a critical capability for future ISRU.

Hazards of Human Spaceflight

1 Space Radiation

Invisible to the human eye, radiation increases cancer risk, damages the central nervous system, and can alter cognitive function, reduce motor function and prompt behavioral changes.

2 Isolation and Confinement

Sleep loss, circadian desynchronization, and work overload may lead to performance reductions, adverse health outcomes, and compromised mission objectives.

3 Distance from Earth

Planning and self-sufficiency are essential keys to a successful mission. Communication delays, the possibility of equipment failures and medical emergencies are some situations the astronauts must be capable of confronting.

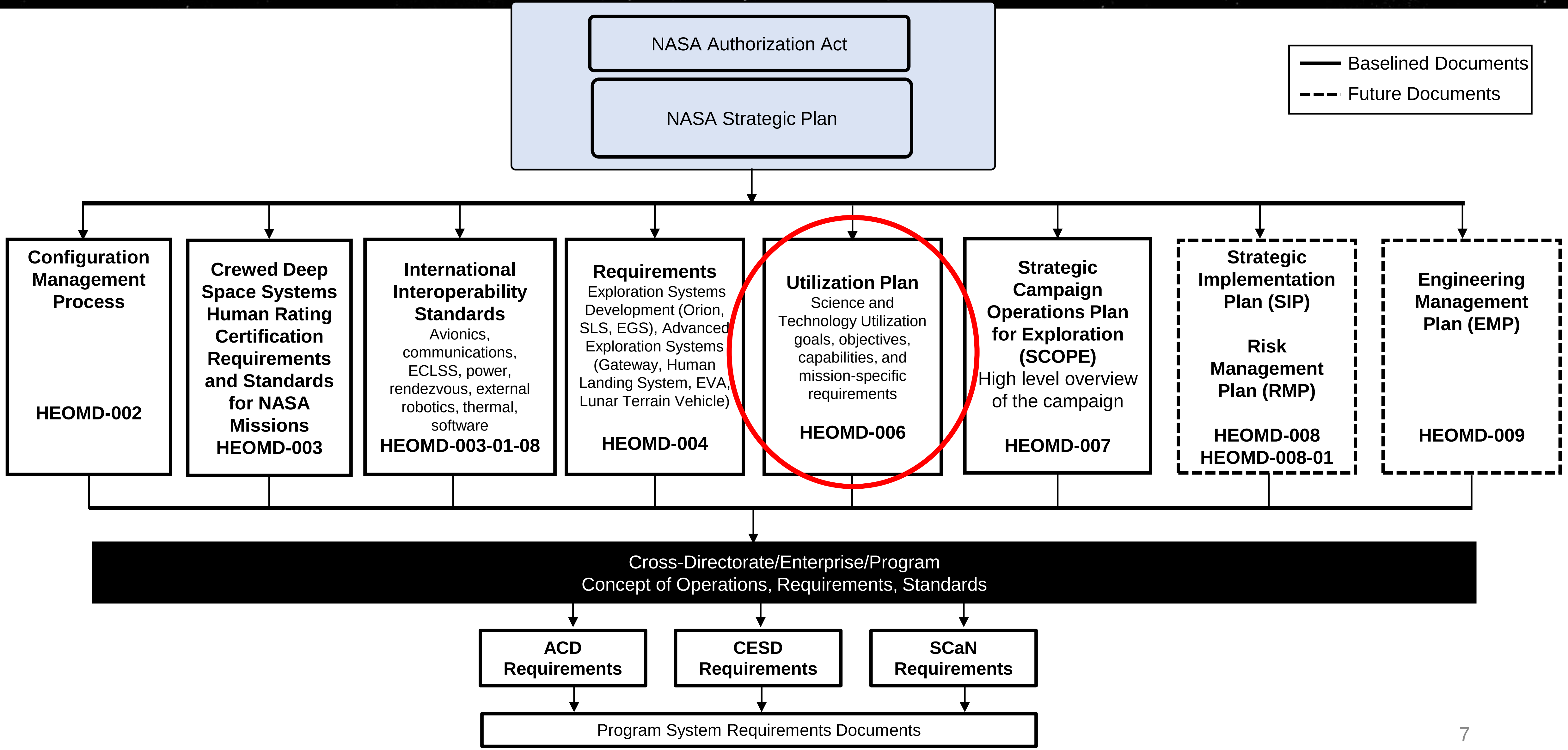
4 Gravity (or lack thereof)

Astronauts encounter a variance of gravity during missions. On Mars, astronauts would need to live and work in three-eighths of Earth's gravitational pull for up to two years.

5 Hostile/Closed Environments

The ecosystem inside a vehicle plays a big role in everyday astronaut life. Important habitability factors include temperature, pressure, lighting, noise, and quantity of space. It's essential that astronauts stay healthy and happy in such an environment.

ESDMD/SOMD Directorate-level Technical Documentation – Current and Planned



SCIENCE & TECHNOLOGY UTILIZATION

INTEGRATING ACROSS MISSION DIRECTORATES

Integrate science and technology goals from mission directorates and international partners to develop HEO utilization goals, objectives and requirements for Artemis missions, and the cross-platform research strategy to prepare for human missions to Mars

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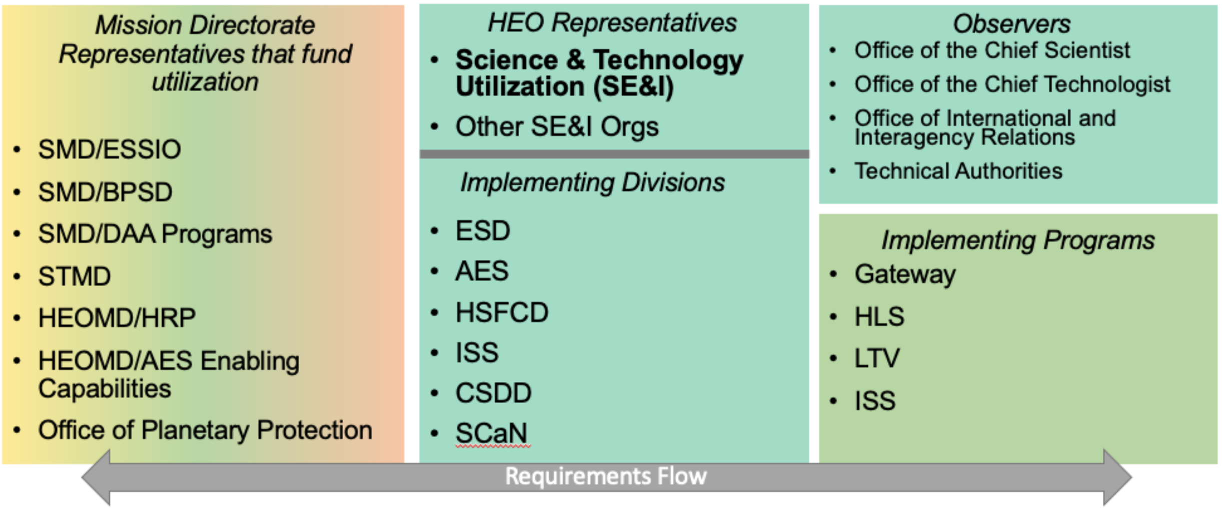
EXAMPLES:

- HEO-006 Utilization Plan joint with SMD and STMD - High level utilization goals, objectives and requirements
  - Utilization capabilities and their phasing over time
  - Mission-specific annexes with mission directorate requirements to enable research solicitations
  - Includes ISS, Commercial LEO, Artemis and Mars
- Co-chair the Utilization Coordination and Integration Working Group (UCIG) with SMD & STMD
- Coordinating HEO process for using our CLPS mass allocations and representative to SMD CLPS manifest selection board

INTEGRATING WITH HEO DIVISIONS

- Work with divisions and users on high-level goals, objectives, and strategic plans
- Interface with AES and ESD on approach to implementation and payload manifest for Artemis
- Ensure science and technology inputs are integrated into Exploration formulation activities

UTILIZATION COORDINATION AND INTEGRATION WORKING GROUP (UCIG) REQUIREMENTS FLOW



Human Spaceflight Utilization Plan (HEOMD-006)

Identifies and describes NASA's science and technology utilization goals and objectives that will be enabled by human missions.

Authority Quad-Directorate:

- Science Mission Directorate (SMD),
- Space Technology Mission Directorate (STMD),
- Space Operations Mission Directorate (SOMD)
- Exploration Systems Development Mission Directorate (ESDMD)

Purpose:

Identify how human missions will support the science and technology communities to conduct fundamental research about our universe and solve the scientific and technological challenges for sustaining and expanding human exploration

Scope: Utilization of ISS/LEO, Artemis, Mars

https://ntrs.nasa.gov/citations/20220005087

National Aeronautics and Space Administration

Exploration Systems Development Mission Directorate (ESDMD)
HEOMD-006
REVISION A
RELEASE DATE: 03/30/2022

EXPLORATION SYSTEMS DEVELOPMENT MISSION DIRECTORATE
UTILIZATION PLAN

This document has been reviewed for Proprietary, CUI, and Export Control (ITAR/EAR) and has been determined to be non-sensitive. It has been released to the public via the NASA Scientific and Technical Information (STI) Process DAA #20220005087

This document was approved by NASA's Exploration Systems Development Mission Directorate (ESDMD), Space Operations Mission Directorate (SOMD), Science Mission Directorate (SMD), Space Technology Mission Directorate (STMD)

March 2022

Utilization Plan
Main Body Goals By NASA Directorate

Goals and Objectives are owned by each mission directorate and updated as needed (e.g., Decadal Survey inputs, Agency Strategic Planning, etc.)

Mission Directorate		Utilization Goals
3.1 SMD	SMD Utilization Goal 1	Enable scientific investigations from the lunar surface, including field relationships, in-situ observations, and sample return, to address the multidisciplinary objectives of the Science Mission Directorate
	SMD Utilization Goal 2	Enable scientific investigations from human spaceflight platforms to address the multidisciplinary objectives of the Science Mission Directorate
	SMD Utilization Goal 3	Enable science investigations on the surface of Mars, in Mars orbit, and in Mars transit
3.2 STMD	STMD Utilization Goal 1	Enable sustainable living and working farther from Earth (“Live”)
	STMD Utilization Goal 2	Enable transformative missions and discoveries (“Explore”)
3.3 ESDMD / SOMD	ESDMD/SOMD Utilization Goal 1	Advance knowledge to support safe, productive human space travel, and enable systems development and testing to reduce health and performance risks for future human exploration
	ESDMD/SOMD Utilization Goal 2	Advance the operational capabilities required for sustainable lunar operations and the first human missions to Mars *including demonstrating approaches to planetary protection.*
3.4 NASA Multi-directorate	Multi-directorate Utilization Goal 1	Enable commercial, interagency, and international partnerships to make space exploration more affordable and sustainable, grow new markets, and increase capabilities

HEOMD-006 Utilization Plan
Annex 1: Cornerstone Capabilities that Enable Multiple Objectives

1.1 MODEL TRAVERSE APPROACHES

1.2 END-TO-END SAMPLE RETURN

1.3 INTEGRATED PLANETARY PROTECTION STRATEGY

1.4 EXTENDED MISSIONS

1.5 INTEGRATED CREW RESEARCH

1.6 ROBOTIC UTILIZATION FOR HEO ASSETS

1.7 INTEGRATED INSTRUMENT STRATEGY

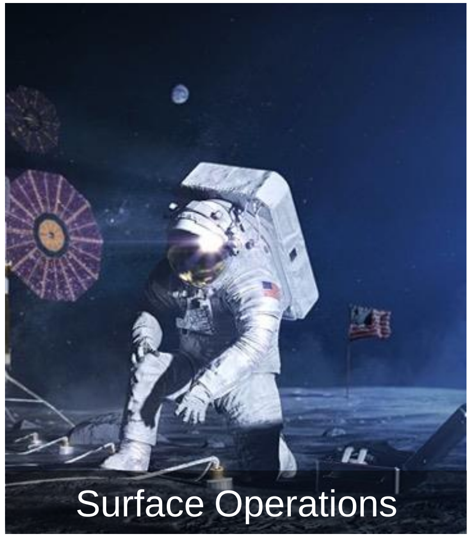
1.8 OPERATIONS IN COLD & SHADOWED REGIONS

Artemis: A Foundation for Deep Space Exploration


Space Launch System


Orion spacecraft


Human Landing System


Surface Operations

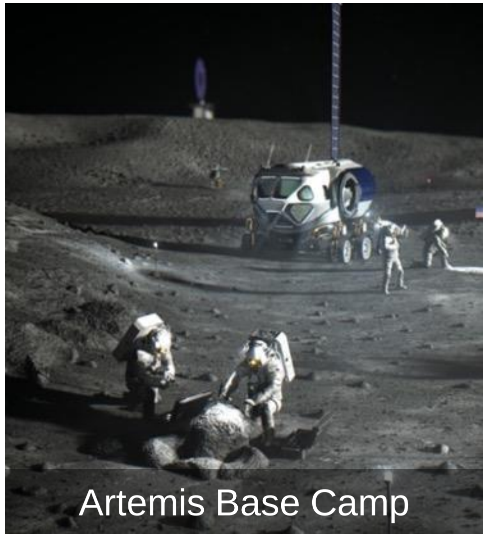

Gateway

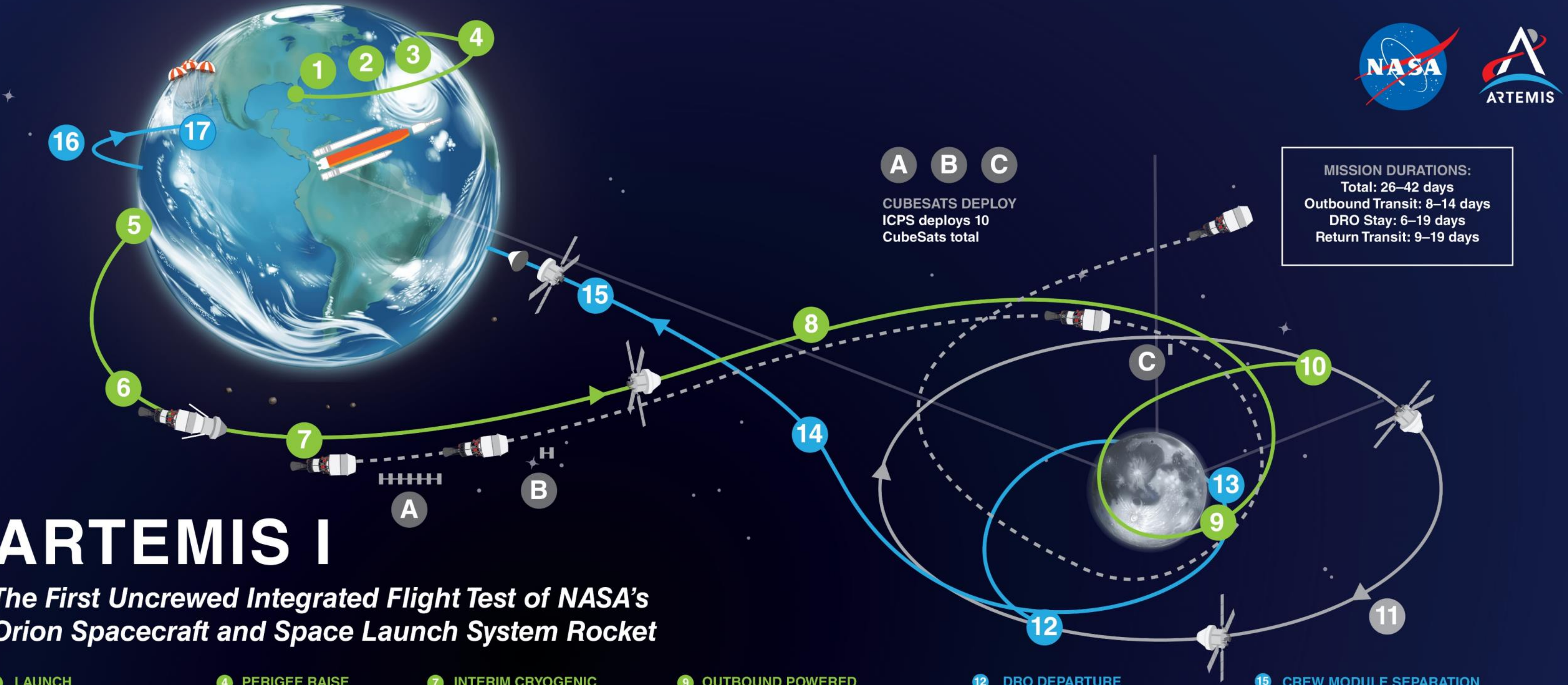

Exploration Ground Systems


Space Communications & Navigation


Surface Mobility


Spacesuits


Artemis Base Camp



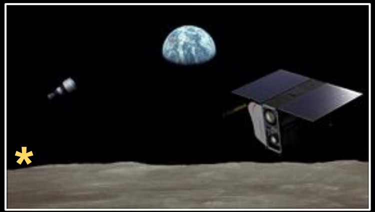
ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

1. **LAUNCH**
   SLS and Orion lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **EARTH ORBIT**
   Systems check with solar panel adjustments.
6. **TRANS LUNAR INJECTION (TLI) BURN**
   Maneuver lasts for approximately 20 minutes.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
   ICPS commits Orion to moon at TLI.
8. **OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS**
   As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).
9. **OUTBOUND POWERED FLYBY (OPF)**
   60 nmi from the Moon; targets DRO insertion.
10. **LUNAR ORBIT INSERTION**
    Enter Distant Retrograde Orbit.
11. **DISTANT RETROGRADE ORBIT**
    Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.
12. **DRO DEPARTURE**
    Leave DRO and start return to Earth.
13. **RETURN POWERED FLYBY (RPF)**
    RPF burn prep and return coast to Earth initiated.
14. **RETURN TRANSIT**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.
15. **CREW MODULE SEPARATION FROM SERVICE MODULE**
16. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
17. **SPLASHDOWN**
    Pacific Ocean landing within view of the U.S. Navy recovery ship.

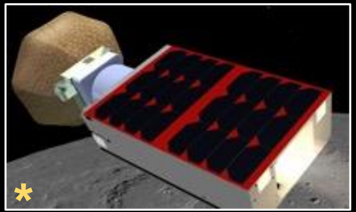
Artemis I CubeSat Payloads

Science and technology investigations and demonstrations paving the way for future, deep space human exploration



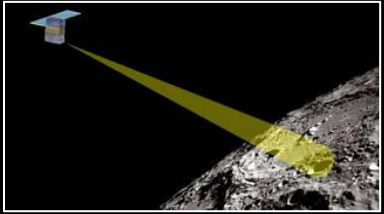
ArgoMoon

Photograph the Interim Cryogenic Propulsion Stage (ICPS) CubeSat deployment, the Earth and Moon using HD cameras and advanced imaging software.



OMOTENASHI

Develop world's smallest lunar lander and observe lunar radiation environment.

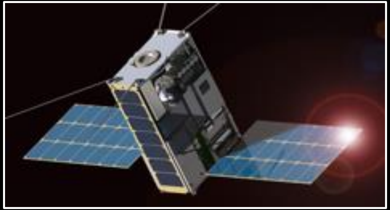


LunIR

Use a miniature high-temperature Mid-Wave Infrared (MWIR) sensor to characterize the lunar surface.

LunaH-Map

Perform neutron spectroscopy to characterize abundance of hydrogen in permanently shaded craters.

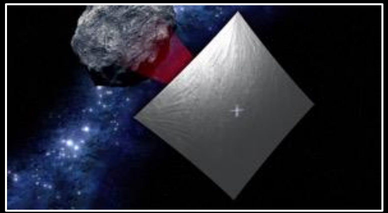


Lunar IceCube

Search for water (and other volatiles) in ice, liquid and vapor states using infrared spectrometer.

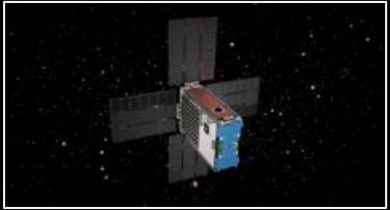
Team Miles

Demonstrate propulsion using plasma thrusters; compete in NASA's Deep Space Derby.



Near-Earth Asteroid Scout (NEA Scout)

Detect target NEA, perform reconnaissance and close proximity imaging.

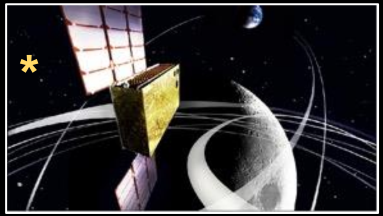


BioSentinel

Use yeast as a biosensor to evaluate the effects of ambient space radiation on DNA.

CubeSat to Study Solar Particles (CuSP)

Measure incoming radiation that can create a wide variety of effects on Earth.



EQUULEUS

Demonstrate trajectory control techniques within the Sun-Earth-Moon region and image Earth's plasmasphere.

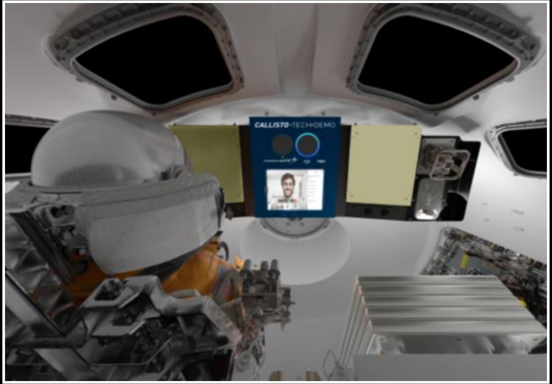
* INTERNATIONAL COLLABORATION

Artemis I Pressurized Payloads

Payloads that will fly inside of the Orion crew module

Radiation Sensors*

There will be three types of sensors, including the ESA Active Dosimeters, Hybrid Electronic Radiation Assessor (HERA), and the Radiation Area Monitor (RAM).

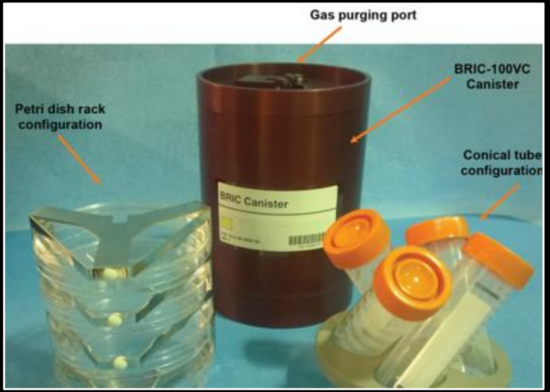


Callisto

Demonstrate voice activated virtual assistant which enables hands free crew interface. Evaluate effectiveness of on board vs. ground supported crew assisted capabilities.

Matroshka AstroRad Radiation Experiment (MARE)*

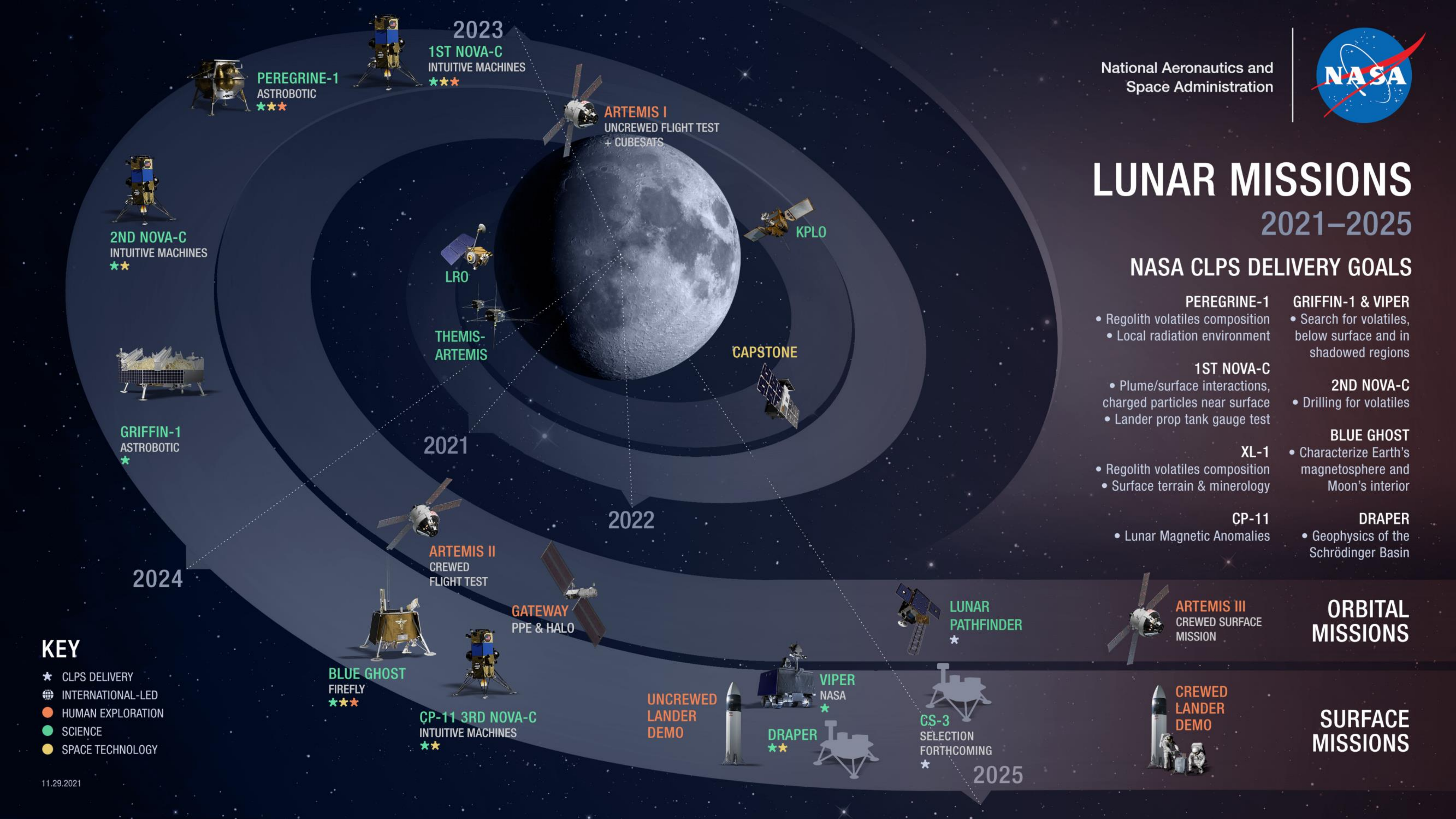
Investigation with DLR and ISA for to evaluation radiation protection vest for astronauts.



Bio-Experiment-1

A battery-powered life sciences payload for biology research beyond low-Earth orbit (LEO). May be as many as four investigations.

* INTERNATIONAL COLLABORATION


National Aeronautics and Space Administration
NASA
LUNAR MISSIONS
2021–2025
NASA CLPS DELIVERY GOALS
PEREGRINE-1
• Regolith volatiles composition
• Local radiation environment
1ST NOVA-C
• Plume/surface interactions, charged particles near surface
• Lander prop tank gauge test
XL-1
• Regolith volatiles composition
• Surface terrain & minerology
CP-11
• Lunar Magnetic Anomalies
GRIFFIN-1 & VIPER
• Search for volatiles, below surface and in shadowed regions
2ND NOVA-C
• Drilling for volatiles
BLUE GHOST
• Characterize Earth's magnetosphere and Moon's interior
DRAPER
• Geophysics of the Schrödinger Basin
2023
1ST NOVA-C
INTUITIVE MACHINES
PEREGRINE-1
ASTROBOTIC
ARTEMIS I
UNCREWED FLIGHT TEST + CUBESATS
2ND NOVA-C
INTUITIVE MACHINES
KPLO
LRO
THEMIS-ARTEMIS
CAPSTONE
GRIFFIN-1
ASTROBOTIC
2021
2022
2024
ARTEMIS II
CREWED FLIGHT TEST
GATEWAY
PPE & HALO
LUNAR PATHFINDER
ARTEMIS III
CREWED SURFACE MISSION
ORBITAL MISSIONS
BLUE GHOST
FIREFLY
CP-11 3RD NOVA-C
INTUITIVE MACHINES
UNCREWED LANDER DEMO
VIPER
NASA
DRAPER
CS-3
SELECTION FORTHCOMING
2025
CREWED LANDER DEMO
SURFACE MISSIONS
KEY
CLPS DELIVERY
INTERNATIONAL-LED
HUMAN EXPLORATION
SCIENCE
SPACE TECHNOLOGY
11.29.2021

SSERVI Overview

SSERVI at a Glance:

Jointly funded by NASA HEOMD and SMD, SSERVI is focused on ***science enabling human exploration and science enabled by human exploration.***

Currently **12 Overlapping U.S. Teams** funded in 2017 and 2019, each with 5-year cooperative agreements.

1000+ publications since SSERVI started in 2013. Many additional conference publications and other scientific products.

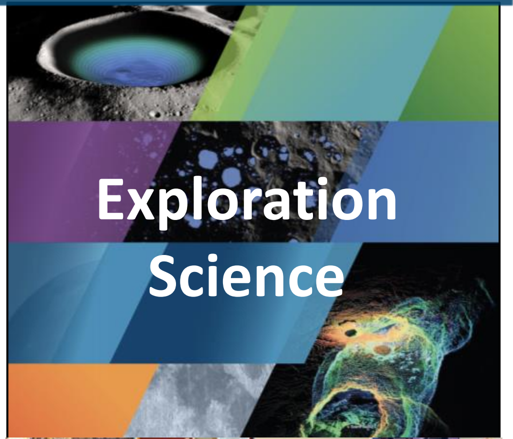
Management of the **Solar System Treks Project (SSTP)**, a visualization tool originally created during Constellation program, at request of NASA HQ.

11 Int'l partners with a focus on lunar science and missions:

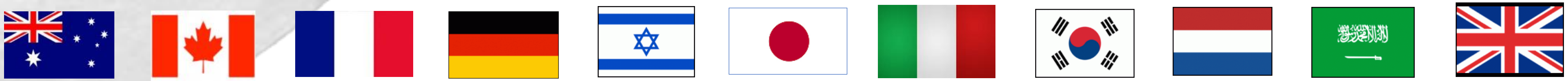
The Solar System Exploration Research Virtual Institute (SSERVI) supports human exploration and scientific discovery by integrating interdisciplinary research to prioritize and resolve key knowledge gaps.

Key Exploration Science Events:

- **NASA Exploration Science Forum (NESF):** Virtual/In-person conference featuring scientific discussions about the Moon and other exploration targets of interest. All past Forum recordings and archives available at sservi.nasa.gov
- **European Lunar Symposium (ELS):** Annual meeting that brings together the U.S. and European lunar science, exploration, and launch communities. ELS documents and video archives: https://els2020.arc.nasa.gov/
- **Solar System Treks Project (SSTP):** A free, web-based application that provides high-resolution images and visualizations of planetary bodies using real spacecraft data. Provides mission planning data analyses to domestic and international lunar missions. New portals and updates released in support of upcoming missions. Access all Trek portals at https://trek.nasa.gov



Australia, Canada, France, Germany, Israel, Italy, Japan, Korea, the Netherlands, Saudi Arabia, United Kingdom



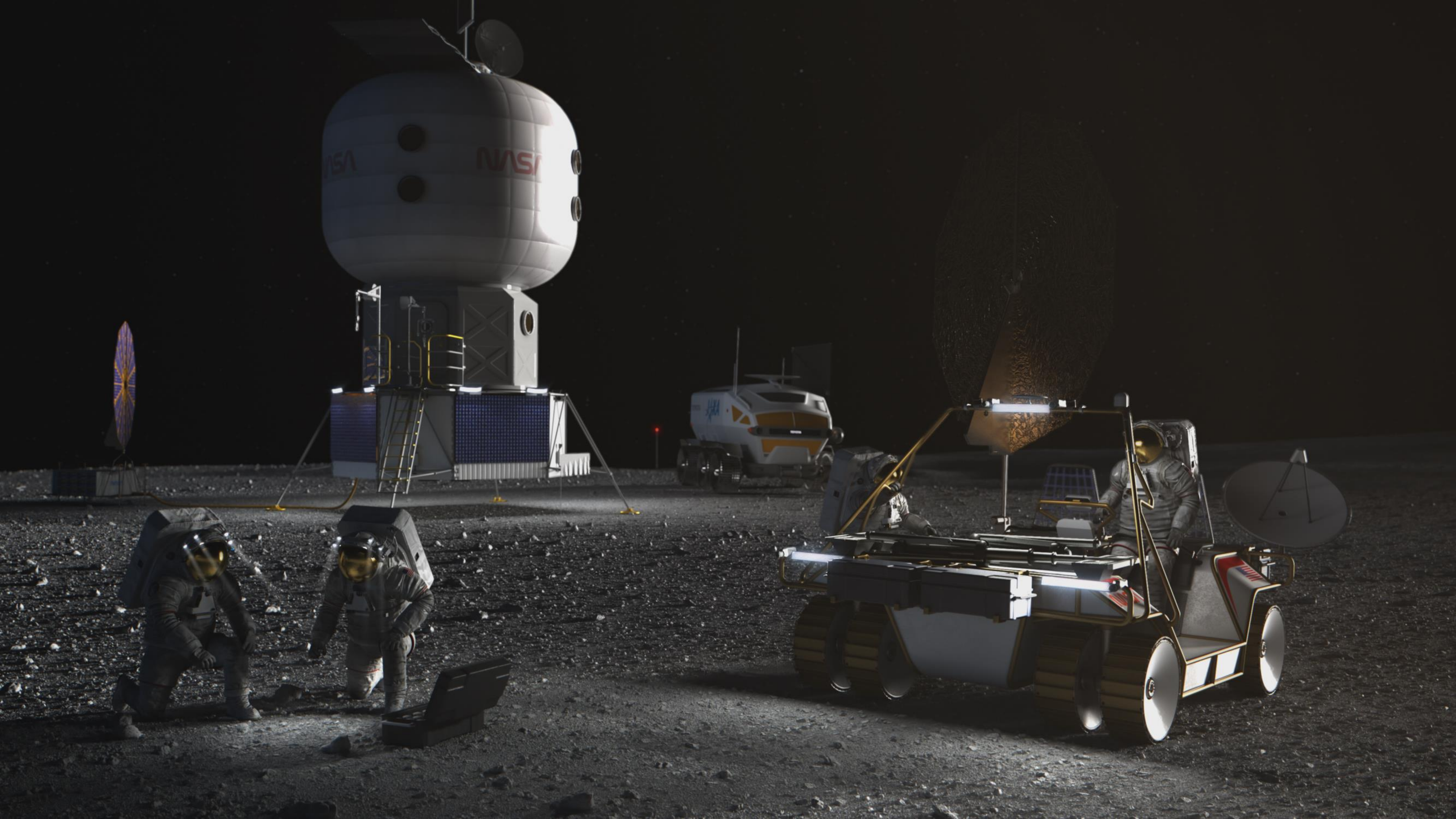
Initial Gateway Science Payloads

Gateway's orbit will offer unique opportunities for heliophysics, human health research, space biology and life sciences, astrophysics, and fundamental physics investigations. As new modules are added, science capability will increase.

Heliophysics Environmental Radiation Measurement Experiment Suite (HERMES): NASA's space weather instrument suite will observe lower energy solar particles critical to scientific investigations of the Sun including the solar winds

European Radiation Sensors Array (ERSA): The European Space Agency's (ESA) radiation instrument package will help provide an understanding of how to keep astronauts safe by monitoring the radiation at higher energies with a focus on space weather

ESA's Internal Dosimeter Array (IDA): Instruments including those provided by Japan Aerospace Exploration Agency (JAXA) will inform for improvements in radiation physics models for cancer, cardiovascular, and central nervous system effects, helping assess crew risk on exploration missions


NASA

NASA